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(54) IMPROVEMENTS IN OR RELATING TO OPTICAL SYSTEMS

(71) We, CANON KABUSHIKI KAISHA, a Japanese Company, of No. 30—2, 3 Chome Shimomaruko, Ota-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an image display system giving a steroscopic effect.

It is known to produce a stereoscopic effect by taking two or more photographs of an object from different view points (which photographs thus possess information regarding parallax with respect to the object) and then to project these photographs on to a lenticular screen, which yields a stereoscopic image. For example, U.S. Patent Specification No. 2,351,033 shows a screen for this purpose and comprising two lenticular sheets each composed of parallel cylindrical lenses, the sheets being disposed in a back-to-back relationship with a diffusing layer positioned therebetween at the focal plane of the cylindrical lenses. This Patent Specification also describes a method of projecting photographs on to such a screen from different angles. The area over which the stereoscopic effect of such a screen can be observed is very limited.

A lenticular screen which enlarges the area in which the stereoscopic effect can be observed is also known. In such a lenticular screen, the diffusing layer is not positioned at the focal plane of the cylindrical lenses, thus differing from the screen disclosed in the above-mentioned U.S. Patent Specification.

This invention aims at providing a stereoscopic display system using a lenticular screen, in which the area in which the stereoscopic effect may be observed is enlarged yet further.

According to this invention, there is provided an image display system for giving a stereoscopic effect, comprising a lenticular screen having the properties of propagating an incident light beam such that the propagated beam has a divergence of up to 20° in the parallax direction and of at least 10° in a direction normal to the parallax direction, means to project an image on to the screen, the image possessing parallax information, and a convergent optical system arranged with its focal point lying within the thickness of the lenticular screen so that the screen may be viewed therethrough.

Preferably, the convergent optical system comprises a convex lens system, although a concave mirror system could be used instead.

A suitable form of the lenticular screen for use in this invention comprises two lenticular sheets positioned one each side of a diffusion plate, each lenticular sheet comprising a plurality of closely-spaced cylindrical lenses on one face and the other face being plane and in contact with the diffusion plate. To obtain the desired effect, the cylindrical lenses of one lenticular sheet should be parallel to those of the other lenticular sheet.

An alternative form of lenticular screen suitable for use in this invention comprises two lenticular sheets arranged back-to-back, each comprising a plurality of closely-spaced parallel cylindrical lenses, the cylindrical lenses of one lenticular sheet extending substantially at right-angles to those of the other lenticular sheet.

An enhanced stereoscopic effect can be obtained if the optical axis of the convergent optical system is inclined to the general plane of the lenticular screen. The angle of inclination should lie in the range of from 3° to 50°, and preferably is substantially 20°.

By way of illustration of this invention, certain specific Examples thereof will now be described, with reference to the accompanying drawings, in which:—

Figure 1 shows a known form of lenticular screen;

Figure 2 shows another known form of lenticular screen, which screen is employed in Examples 1 and 2 of this invention;

Figures 3 and 4 illustrate diagramatically

Examples 1 and 2 of this invention;

Figure 5 shows a lenticular screen which is used in Examples 4 and 5 of this invention; and

Figures 6, 7 and 8 illustrate diagrammatically Examples 3, 4 and 5 respectively of this invention.

Figure 1 shows a lenticular screen 11 which has been used to produce a stereoscopic effect. Lenticular sheets 12 and 13 each comprise a plurality of parallel cylindrical lenses 12_1 and 13_1 having equal focal lengths. The sheets 12 and 13 are arranged in a back-to-back relationship with a diffusion plate 14 disposed therebetween at the common focal plane of the cylindrical lenses 12_1 and 13_1 of the lenticular sheets 12 and 13 respectively.

Pictures are projected on the screen 11 by projection lenses 18_1, 18_2, light flux 15 from lens 18_1 falling on the screen 11. A line image 16 is focussed by a cylindrical lens 12_1, and light from the line image 16 leaves one of the cylindrical lenses 13_1 as flux 17.

The light fluxes from all of the lenses 13_1 emanating from projector lens 18_1 are convergent on plane 19_1 — i.e. an image projected on to the screen 11 from projector 18_1 can be totally observed at plane 19_1. Since the light flux from each cylindrical lens 13_1 will converge at a different area on the plane 19_1, only one portion of the image being projected on the screen by the projector lens 18 can be observed. Plane 19 is the plane at which an image from projector lens 18_2 can be observed, but again the area at which light from each lens converges will be different.

Stereoscopic vision of an image can be obtained by viewing the images of the two pictures projected on the screen by viewing with two eyes, one in each observation area 19_1 and 19_2.

However, with the lenticular screen described above, since the focal distances of the cylindrical lenses 12_1, 13_1 are equal and the diffusion plate is positioned at the focal plane of each lens 12_1, 13_1, the size of the area at which observation can be made is limited to the size of the aperture of the projector lens.

A screen for enlarging the area at which observation can be made is also known. Such a screen can propagate an incident beam with a divergence of up to 20° in the parallax direction (i.e. normally parallel to the length of the lenses 12_1 and 13_1) and of at least 10° in a direction normal to the parallax direction.

The composition of such a screen is shown in Figure 2. The screen 21 comprises two lenticular sheets 22 and 23, and a diffusion plate 24, the lenticular sheets 22 and 23 having cylindrical lenses 22_1 and 23_1 respectively. Screen 21 differs from that shown in Figure 1 insofar as the diffusion plate 24 is not positioned at the focal plane of the cylindrical lenses 22. Instead, the diffusion plate 24 is positioned in front of the focal plane of the cylindrical lens 22_1, and therefore a light beam entering one of the cylindrical lenses 22_1 from a projector lens 25_1 or 25_2, forms an out-of-focus line image 26_1 or 26_2. That is, a light source of considerable width is formed on screen 24. Therefore, light from the screen 24 leaves the cylindrical lens 23_1 as a divergent beam. These beams all overlap at area 28_1 for projector lens 25_1 or at area 28_2 for projector lens 25_2. When the eye of an observer is in one of these areas, it is possible to observe all of the image of a picture projected on to the screen 21 by one of the projector lenses. Therefore, when the left and right eyes of an observer are respectively in areas 28_1 and 28_2, a stereoscopic effect will be obtained.

It will be understood that the extent of the areas 28_1 and 28_2 in which observation can be made are enlarged in the parallax direction (i.e. the direction parallel to the screen in the drawing) as compared to the areas 19_1 and 19_2 of Figure 1. This enlargement is generated by virtue of the diffusion plate 24 being spaced from the focal plane of all of the cylindrical lenses 22_1, and the extent of the enlargement is determined by the relative position of the diffusion plate and the cylindrical lenses 22_1 and 23_1. However, it is found that a spread of up to 20° only is possible in the parallax direction. Also, the spread of the beam in a direction normal to the parallax direction occurs because the cylindrical lenses 22_1 and 23_1 have no imaging effect in that direction coupled with the action of the diffusion plate 24. However, it is desirable that there is a spread of at least 10°.

As has been explained above, the screen shown in Figure 2 is very effective for enlarging the area in which observation can be made. However, practically, the areas 28_1 and 28_2 in which observations can be made are preferred to be approximately the size of the pupils of a human eye. The reason for this will be explained below, referring to Figure 3, and the ray paths present when lens 31 is absent.

In Figure 3, projectors 32_1 to 32_3 are used to project pictures 33_1 to 33_3 on to a screen 21 of the construction shown in Figure 2. In Figure 3, the functions of the projectors 32 and the screen 21 are shown mostly only so far as the lower parts of their projected beams are concerned. The optical axis of projector 32_2 is positioned on the centre line of the screen 21, and the action of this projector will be explained first.

Light projected along the optical axis of projector 32_2 is incident on the screen 21 at its centre line. This light is spread by the

screen over an angle of up to 20°, as shown by the area shaded by solid oblique lines. Light from the lower extremity of the projector 32_2 is spread by up to 20° in a similar way by the screen 21, as shown by the broken oblique shading. However, these two beams shaded by oblique lines are divergent, as is apparent in the drawing. In order for an observer to see the entire image projected over the lower half of the screen 21, both of these beams must enter the pupil of an observer's eye — i.e. the size of his pupil must be equal to the size of the double-headed arrow "A" in the drawing. If the lower beam shown by the broken oblique lines does not enter the observer's pupil, a portion of the image falling on the screen from the projector 32_2 will not be seen. It should be noted that Figure 3 is purely diagrammatic, and is drawn in a most exaggerated manner to make clear the principles. A screen such as that shown in Figure 3 operates in practice such that the actual separation of the two light beams is very much smaller than that shown in the drawing; neverthless it is a fact that these two light fluxes do separate.

This invention provides an image display system which reduces the disadvantage just-discussed relating to the screen shown in Figure 2. To make this clear, certain specific Examples of this invention will be described in detail.

Example 1 (shown in Figure 3).

A lens 31, having a converging function, is positioned so that its focal plane lies within the thickness of a lenticular screen 21, having the construction shown in Figure 2. Projectors 32_1 to 32_3 are positioned as described above, and project light which leaves the screen 21 in the manner described. Light at the lower extremity from the projected beam of projector 32_2 is refracted by the lens 31 towards the optical axis, as shown by the beam shaded with solid oblique lines, and this refracted light overlaps the divergent light from projector 32_2 and incident on the screen along the optical axis. Other beams, for example a beam which is incident on the screen at its upper extremity, are also convergent to overlap each other at area 34_2, in a similar manner. Therefore, when an eye 35_1 is positioned at area 34_2, a full image of the picture 33_2 projected on the screen by the projector 32_2 may be seen. The area 34_2 is wider than the area shown in Figure 1 at which the image can be seen by as much as the spread of the beam — that is, up to 20°. Other areas will be generated by the other projectors — for example, area 34_3 by projector 32_3. When the left and right eyes of an observer are located respectively at the areas 34_2 and 34_3, a stereoscopic image can be observed.

In this Example, the screen 21 is positioned so that the front focal point of the lens 31 lies within the thickness of the screen and an image, and the image on the projected on the screen will be observed through the lens 31 as a virtual image of that lens. Therefore, this Example has the advantage that the eyes of an observer will be focused to the position of the virtual image (and not on the screen), and hence the observer will not notice the presence of the screen. Also, when a lens 31 generating considerable distortion is used — for example, a Fresnel lens — the left and right images will have slightly different distortions, and this difference leads to a further stereoscopic effect.

Example 2 (shown in Figure 4).

In this Example, a further stereoscopic effect can be obtained. The arrangement of this Example is almost the same as that of Example 1, but differs in that the screen 21 is inclined to the general plane of lens 31.

Because the distance between the lens 31 and the image on the screen 21 is different (and in the drawing, is shorter) at the upper part of the screen 21 from that at the lower part of the screen, the upper part of the image on the screen 21 is enlarged by the lens 31 by a smaller amount than that at the lower part.

In a general scenic view, the upper part will usually include sky, or mountains and so on, whilst the lower part will usually have nearer objects, such as human beings and so on. Therefore the distant part of the view (that is, the portion projected on to the upper part of the screen) is enlarged by a smaller degree, while the near part of the view (that is, the portion projected on to the lower part of the screen) is enlargd by a greater degree. Thus, a perspective effect can be obtained.

The angle of inclination of the lens 31 to the screen 21 should be from 3° to 50°, and preferably 20°. It would of course be possible to incline relatively the screen and lens in the opposite sense to that shown in the drawing — thus so that the lower edge of the screen is nearer the lens than the upper edge.

It will be appreciated that this invention is applicable to other forms of screen besides those shown in Figure 2, provided that the screen has the properties of propagating incident light with an angle of divergence of up to 20° in the parallax direction, and of at least 10° in a direction normal thereto.

Figure 5 shows a different form of screen from that shown in Figure 2. Light incident on this screen is propagated with a divergence of up to 20° in the parallax

direction, and of at least 10° in the direction normal to the parallax direction.

The screen 51 comprises two lenticular sheets 52 and 53, having cylindrical lenses 52_1 and 53_1 respectively. The two lenticular sheets 52 and 53 are positioned so that the cylindrical lenses 52_1 of sheet 52 are normal to the cylindrical lenses 53_1 of sheet 53.

When light beams 54_1 and 54_2 both having circular cross-sections, are incident on the screen 51, the beams 54_1 and 54_2 are, after initially being made convergent, made divergent in the lateral direction (parallax direction) by the action of the cylindrical lenses 52_1 on the incident lenticular sheet 51. The laterally-divergent beam then enters the lenticular sheet 53 and is made divergent in the vertical direction (that is, the direction perpendicular to the parallax direction) by the action of the cylindrical lenses 53_1. The angle of divergence is determined by the focal distance and pitch (that is, the F-number) of the cylindrical lenses 52_1 and 53_1. By selecting the focal distance and pitch suitably a screen can be made having the properties that an incident beam is propagated with an angle of divergence of up to 20° in the parallax direction and of at least 10° in a direction vertical to the parallax direction.

This screen 51 also has similar drawbacks as in the screen explained with reference to Figure 2.

Example 3
(shown in Figure 6).

This Example employs the screen shown in Figure 5.

A screen 51 is positioned at the focal plane of a lens 31, as in Example 1 shown in Figure 3. Pictures 62_1, 62_2 are projected on the screen 51 through a projector 61 and an arrangement of mirrors 63_1, 63_2, 64_1 and 64_2. This arrangement for projecting a stereoscopic pair of images is well known in this art. Light from different parts of the screen 51, functioning as described with reference to Figure 5, is made to overlap to enter the pupils 65_1 andc 65_2 of an observer by the action of lens 31, as explained in Example 1. Therefore the same effect as in Example 1 can be obtained.

Example 4
(shown in Figure 7).

This Example employs a screen 51 which is inclined with respect to a lens 31, as in Example 2 shown in Figure 4. By this, a further stereoscopic effect over that of Example 3 can be obtained.

In this Example, a different arrangement of projector and mirrors 71 and 72 is shown from the projector optical system of Figure 6, but this arrangement is also well known.

Example 5
(shown in Figure 8).

This Example is almost the same as Example 3 shown in Figure 6, but differs in that another projector optical system is used.

A cathode ray tube 81 is used to project in turn left and right images on to a rotating mirror 83. The rotation of the mirror is synchronised to the projection of left and right image, such that when a right image is projected, the mirror is at the position shown by a solid line, and the right image is projected on to the screen 51 through a mirror 85. When a left image is projected, the rotating mirror is at the position shown by a broken line, and the left image is projected on to the screen through a mirror 84.

In place of the cathode-ray tube 81, a light valve of Schlieren type, such as an "eyed-hole", may be used. Furthermore, this embodiment is suitable for the projection of motion images with a stereoscopic effect. Also it may be used for projecting other images, simply by removing the rotating mirror 83.

In the above-described Examples, it is clear that a concave mirror could be used instead of the convex lens to produce the required effect. Also, the projected images could be holograms or electrostatic photographs as well as conventional photographs.

It will be appreciated that with this invention, a bright image may be observed, because the image forming optical system comprising a convex lens or a concave mirror serves to condense the light rays. When a lenticular screen having orthogonal lenses is used, the diffusion angles in each direction may be selected by suitable design, so that a larger quantity of the projected light may be used effectively.

WHAT WE CLAIM IS:—

1. An image display system for giving a stereoscopic effect, comprising a lenticular screen having the properties of propagating an incident light beam such that the propagated beam has a divergence of up to 20° in the parallax direction and of at least 10° in a direction normal to the parallax direction, means to project an image on to the screen, the image possessing parallax information, and a convergent optical system arranged with its focal point lying within the thickness of the lenticular screen so that the screen may be viewed therethrough.

2. An image display system as claimed in claim 1, wherein the convergent optical system comprises a convex lens system.

3. An image display system as claimed in claim 1, wherein the convergent optical

system comprises a concave mirror system.

4. An image display system as claimed in any of the preceding claims, wherein the lenticular screen comprises two lenticular sheets positioned one each side of a diffusion plate, each lenticular sheet comprising a plurality of closely-spaced cylindrical lenses on one face and the other face being plane and in contact with the diffusion plate.

5. An image display system as claimed in claim 4, wherein the cylindrical lenses of one lenticular sheet are parallel to those of the other lenticular sheet.

6. An image display system as claimed in any of claims 1 to 3, wherein the lenticular screen comprises two lenticular sheets arranged back-to-back, each comprising a plurality of closely-spaced parallel cylindrical lenses, the cylindrical lenses of one lenticular sheet extending substantially at right-angles to those of the other lenticular sheet.

7. An image display system as claimed in any of the preceding claims, wherein the optical axis of the convergent optical system is inclined to the general plane of the lenticular screen.

8. An image display system as claimed in claim 7, wherein the angle of inclination lies in the range of from 3° to 50°.

9. An image display system as claimed in claim 8, wherein the angle of inclination is substantially 20°.

10. An image display system substantially as hereinbefore described in any one of Examples 1 to 5 and as shown in Figures 3 and 4, and 6 to 8 of the accompanying drawings.

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1403783 COMPLETE SPECIFICATION

8 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG.1

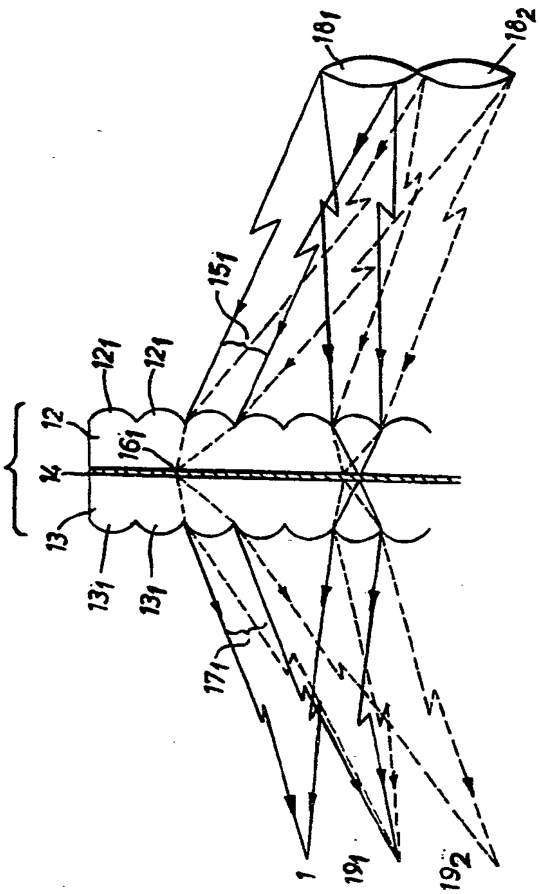
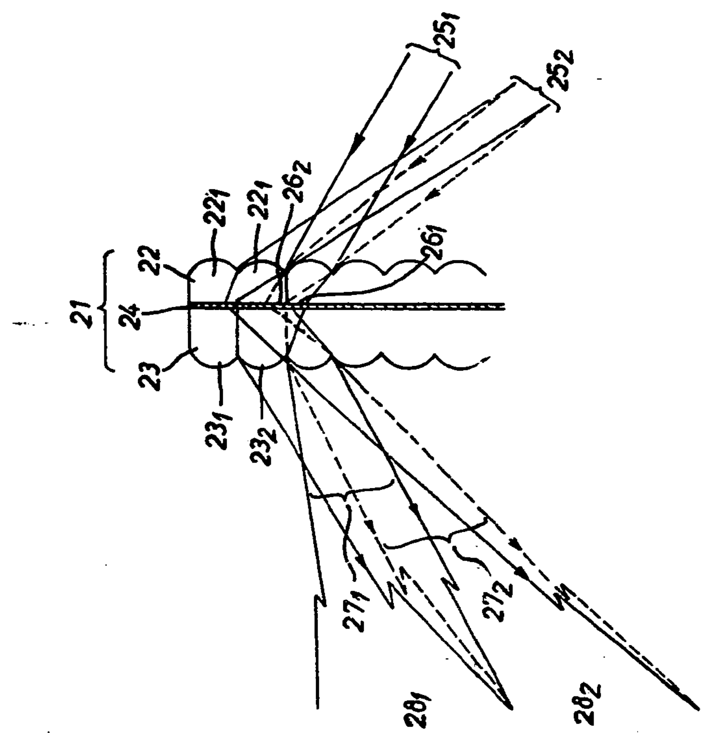


FIG.2



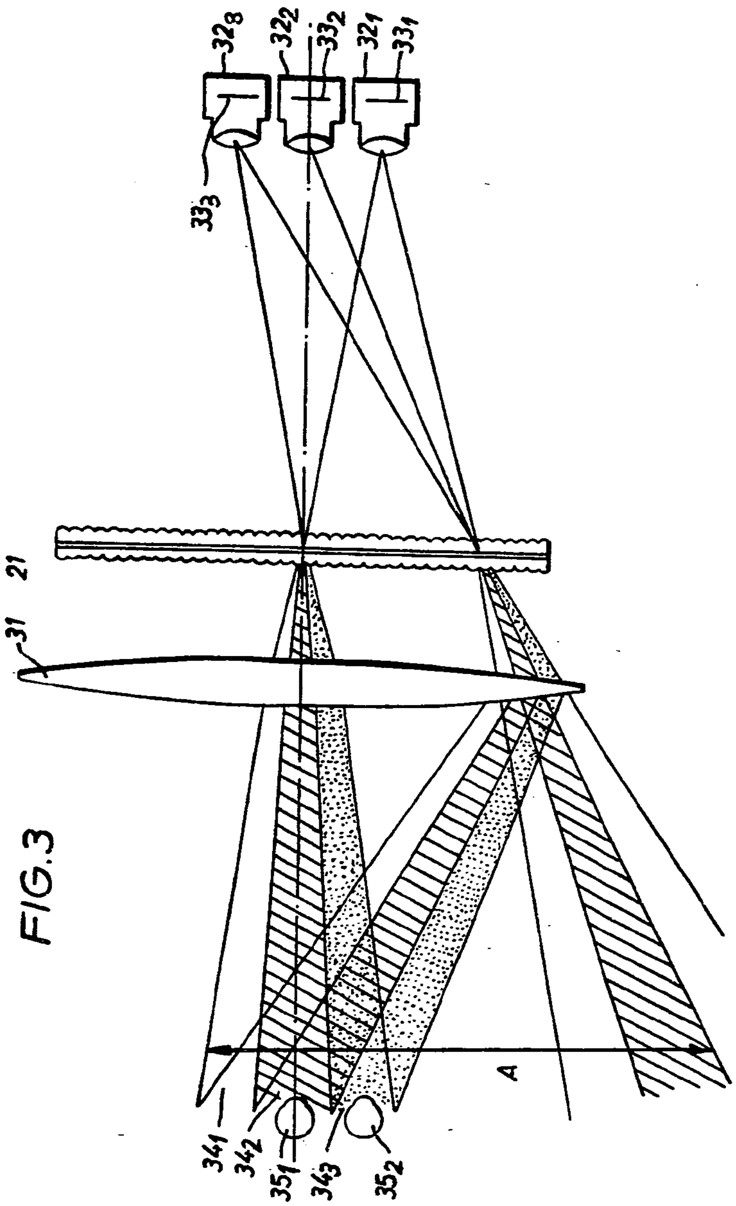


FIG.3

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8 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 4

FIG. 4

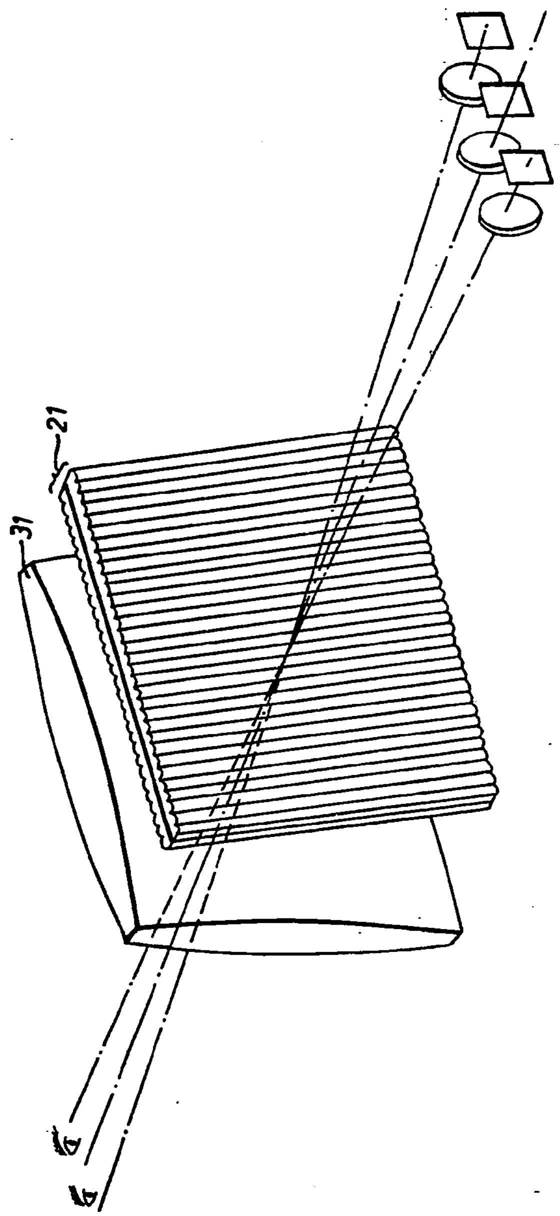
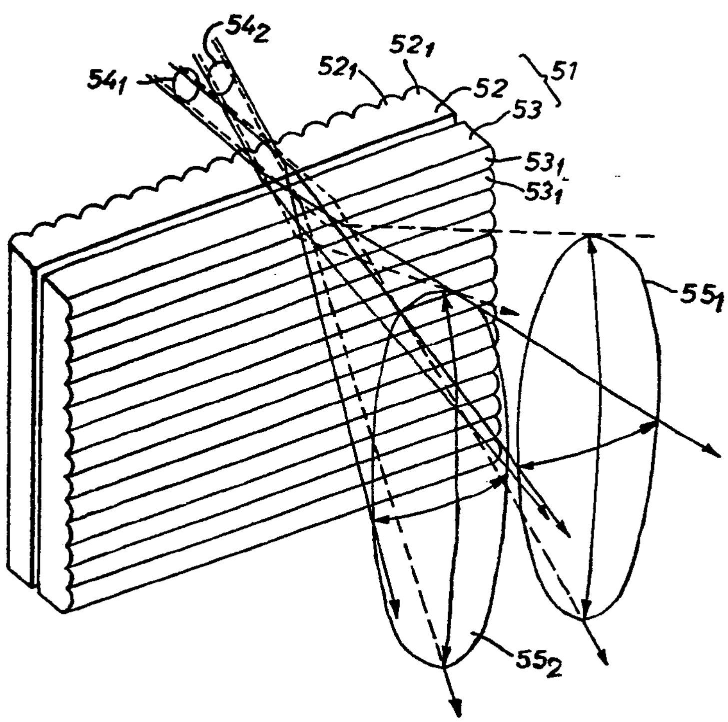


FIG. 5



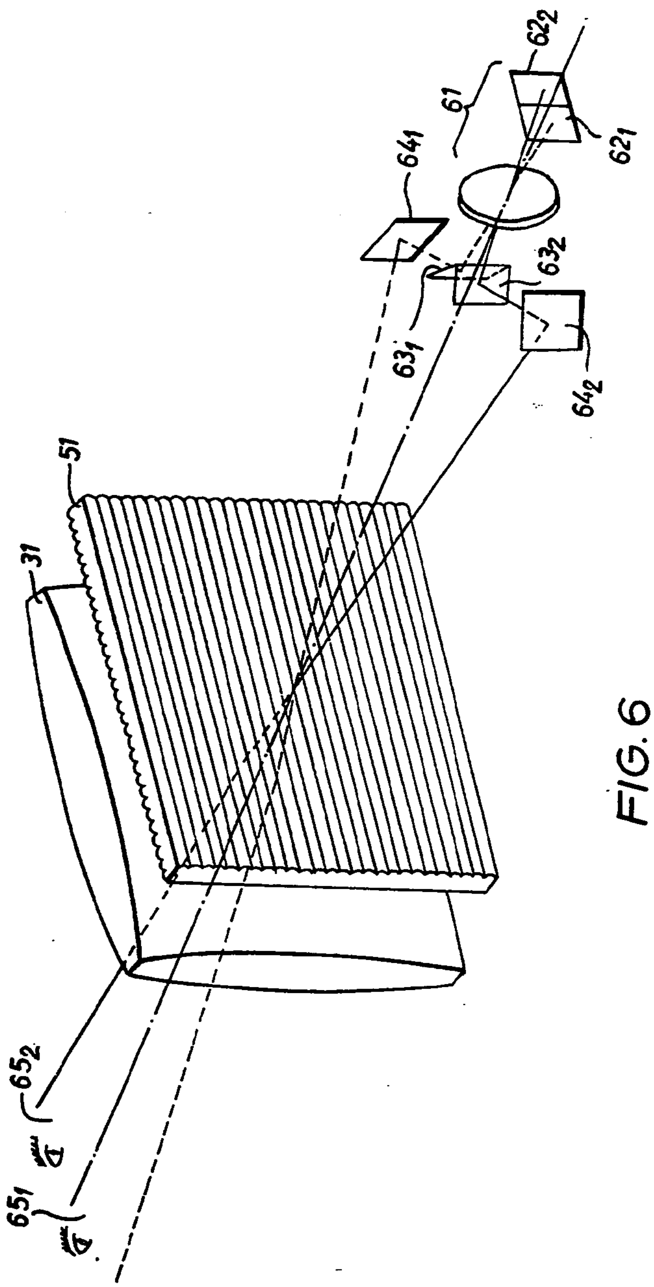


FIG.6

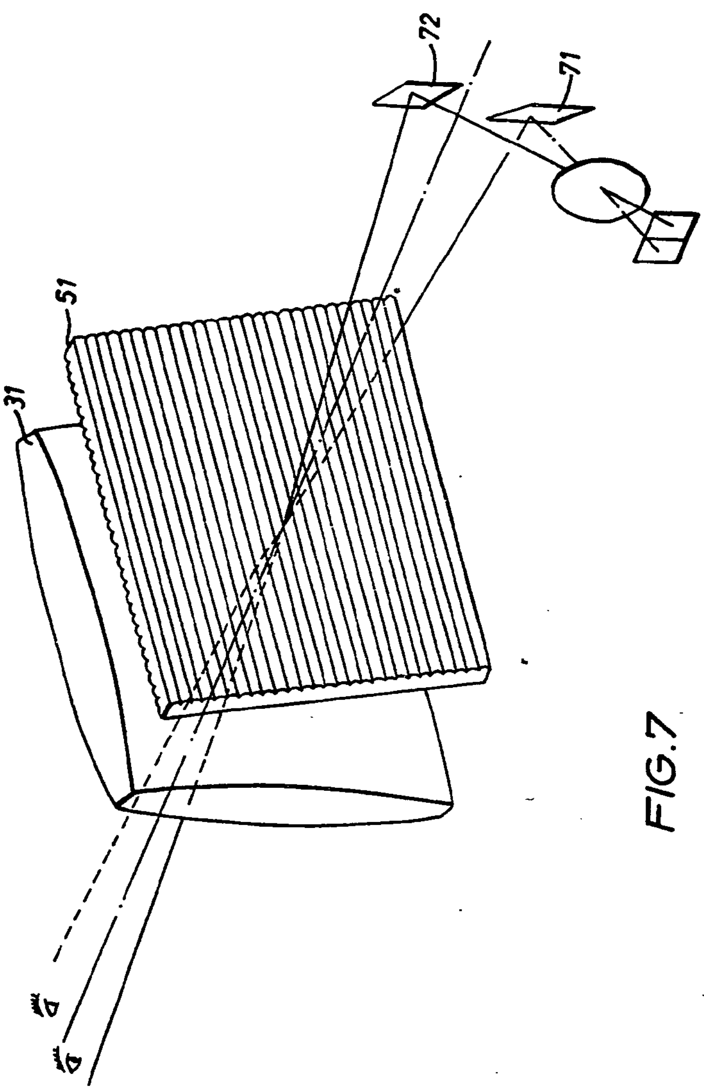


FIG.7

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8 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 8

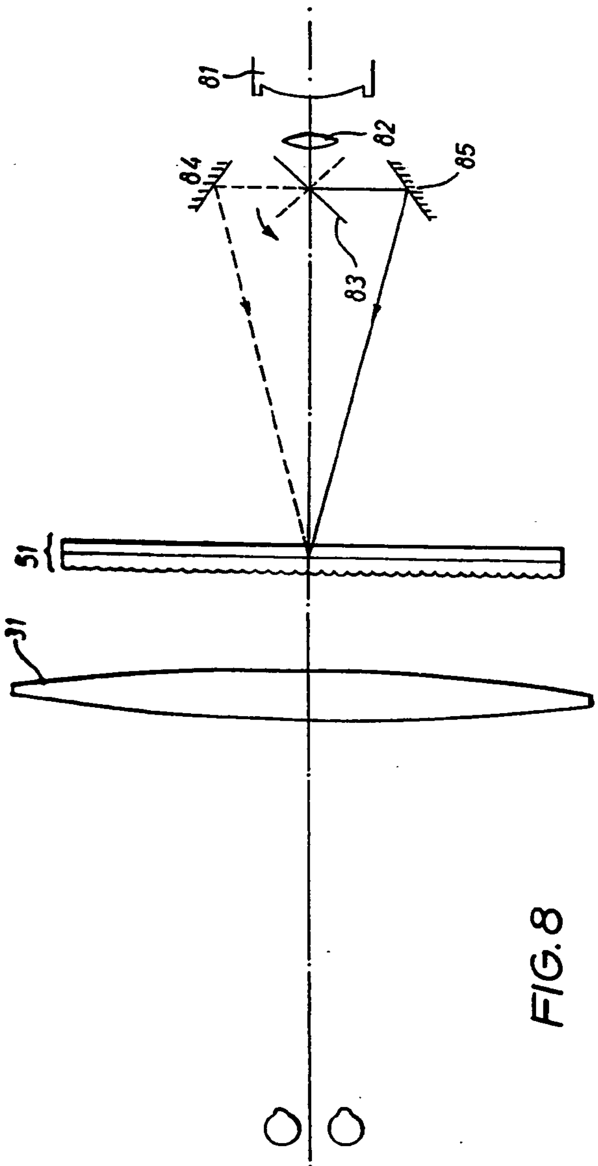

FIG.8